41. H.-H. Wellhöner, *Naunyn-Schmiedebergs Arch. Pharmakol. Exp. Pathol.* **262**, 29 (1969).
42. R. Shipolini, A. F. Bradbury, G. L. Callewaert, C. A. Vernon, *Chem. Commun.* **1967**, 679 (1967).
43. P. Haux, H. Sawerthal, E. Habermann, *Hoppe-Seylers Z. Physiol. Chem.* **348**, 737 (1967).
44. G. L. Callewaert, R. Shipolini, C. A. Vernon, *Fed. Eur. Biochem. Soc. Lett.* **1**, 111 (1968).
45. E. Habermann and P. Haux, unpublished data.
46. H. Breithaupt and E. Habermann, *Naunyn-Schmiedebergs Arch. Pharmakol. Exp. Pathol.* **261**, 252 (1968).
47. B. Fredholm and Ö. Hägermark, *Acta Physiol. Scand.* **69**, 304 (1967); B. Fredholm, *Biochem. Pharmacol.* **15**, 2037 (1966); B. Fredholm and Ö. Hägermark, *Acta Physiol. Scand.* **71**, 357 (1967); *ibid.* **76**, 288 (1969).
48. A. M. Rothschild, *Brit. J. Pharmacol.* **25**, 59 (1965).
49. R. D. Higginbotham and S. Karnella, *J. Immunol.* **106**, 233 (1971).
50. P. Haux, *Hoppe-Seylers Z. Physiol. Chem.* **350**, 536 (1969).
51. R. Jaques and M. Schachter, *Brit. J. Pharmacol.* **9**, 53 (1954).
52. K. D. Bhoola, J. Calle, M. Schachter, *J. Physiol. London* **159**, 167 (1961); G. Abrahams, thesis, University of Würzburg (1955); F. Albl, thesis, University of Würzburg (1956); W. Neumann and E. Habermann, in *Venoms*, E. Buckley and N. Porges, Eds. (AAAS, Washington, D.C., 1956), p. 171.
53. N. Emmelin and W. Feldberg, *J. Physiol.* **106**, 440 (1947).
54. M. Schachter, *Ann. N.Y. Acad. Sci.* **104**, 108 (1963).
55. For review see J. J. Pisano, in *Handbook of Experimental Pharmacology* (Springer-Verlag, New York, 1970), vol. 25, p. 589.
56. A. Anastasi, G. Bertaccini, V. Erspamer, *Brit. J. Pharmacol.* **27**, 479 (1966).
57. E. Habermann, *Biochem. Z.* **329**, 1 (1957).
58. S. A. Barker, S. I. Bayyuk, J. S. Brimacombe, D. J. Palmer, *Nature* **199**, 693 (1963).
59. R. A. Shipolini, G. L. Callewaert, R. C. Cotrell, S. Doonan, B. E. C. Banks, *Eur. J. Biochem.* **20**, 459 (1971).
60. L. L. M. van Deenen and G. H. de Haas, *Annu. Rev. Biochem.* **35**, 157 (1966).
61. T. Dakhil and W. Vogt, *Naunyn-Schmiedebergs Arch. Exp. Pathol. Pharmakol.* **243**, 174 (1962).
62. E. Habermann and B. Krusche, *Biochem. Pharmacol.* **11**, 400 (1962).
63. ———, *Naunyn-Schmiedebergs Arch. Exp. Pathol. Pharmakol.* **230**, 538 (1957).
64. B. M. Braganca and I. H. Quastel, *Biochem. J.* **53**, 88 (1953).
65. D. E. Green and S. Fleischer, *Biochim. Biophys. Acta* **70**, 554 (1963).
66. I. Aravindakshan and B. M. Braganca, *ibid.* **31**, 463 (1959).
67. R. A. Shipolini, G. L. Callewaert, R. C. Cotrell, C. A. Vernon, *Fed. Eur. Biochem. Soc. Lett.* **17**, 39 (1971).
68. D. Hegner and M. Frimmer, *Naunyn-Schmiedebergs Arch. Pharmakol. Exp. Pathol.* **257**, 282 (1967).
69. B. Högberg and B. Uvnäs, *Acta Physiol. Scand.* **48**, 133 (1960).
70. H. Schmidt, W. Creutzfeldt, E. Habermann, *Klin. Wochenschr.* **45**, 163 (1967).
71. M. Frimmer, *Deut. Med. Wochenschr.* **91**, 33 (1966).
72. G. Waldvogel and M. Frimmer, *Naunyn-Schmiedebergs Arch. Pharmakol. Exp. Pathol.* **258**, 321 (1967); F. Lutz and M. Frimmer, *ibid.* **260**, 173 (1968).
73. C. Moroz, A. de Vries, M. Sela, in *Animal Toxins*, F. E. Russell and P. R. Saunders, Eds. (Pergamon Press, New York, 1967), p. 303.
74. C. Rochat, H. Rochat, F. Miranda, S. Lissitzky, *Biochemistry* **6**, 578 (1967).
75. H. Moussatché, J. M. Gonçalves, G. D. Vieira, A. Hasson, in *Venoms*, E. Buckley and N. Porges, Eds. (AAAS, Washington, 1956), p. 275.
76. C. Y. Lee, *Clin. Toxicol.* **3**, 457 (1970).
77. I. L. Thon and B. Uvnäs, *Acta Physiol. Scand.* **71**, 303 (1969).
78. P. Naranjo, in *Handbook of Experimental Pharmacology* (Springer-Verlag, New York, 1966), vol. 18, pt. 1, p. 179.

Residuals Charges for Pollution Control: A Policy Evaluation

Residuals charges are more effective and efficient than current policies of environmental regulation.

A. Myrick Freeman III and Robert H. Haveman

As environmental degradation has emerged as a public policy issue, interest in alternative strategies for controlling environmental pollution has increased. Our growing awareness of the failure of present pollution control strategies to cope effectively with the problem has contributed significantly to this willingness to examine alternatives (*1–3*). Some of the proposed alternatives would not alter the basic thrust of present policies, but would only do more, do it better (we hope), and do it faster. However, there has also been growing interest in one alternative which would involve a significant departure from the present policies. This is the strategy of creating economic incentives for pollution control by levying taxes or charges on wastes (residuals) discharged to the environment.

Five years ago, this residuals charge strategy was opposed by businessmen, political leaders, and environmental groups. Only academic economists (and some of their number who had infiltrated government) could be found to espouse this position. Yet today, the President and his Council of Environmental Quality, environmental groups, and numerous members of Congress have endorsed this strategy, at least in principle (*4*, pp. 136–139, 287, and 303–305; *5*).

Congress now has before it a wide range of pollution control bills based on an economic incentive strategy. The Administration has proposed both a tax on lead additives in gasoline and on sulfur oxide emissions from fossil fuel combustion (*6*). Since November 1969, Senator William Proxmire has gathered increasing support for his bill to impose charges on industrial effluents discharged to public watercourses (*7*). Charges on effluents causing water pollution have been or are being considered in several states, including Maine, Wisconsin, New Jersey, and Illinois. And Vermont has enacted a modified form of charging for effluents that is designed to accelerate compliance with the provisions of state-issued licenses for the discharge of wastes (*8*). All of these proposals have the following common characteristic: either directly or indirectly they would raise the cost of discharging harmful wastes to the environment. Thus their aim is to induce firms, municipalities, and individuals subject to the charge to curb their discharges of wastes and ultimately to reduce the damages caused by these discharges.

At an abstract level the logic of the argument in favor of residuals charges is impeccable. Even at the practical level of policy implementation, the case for such a strategy appears very strong indeed. Yet despite the increasing interest in the concept and the growing support for specific proposals, the public debate has been clouded by confusion and misconceptions. This has allowed some assertions questioning the efficacy, feasibility, and effectiveness of residuals charges to gain an unwar-

Dr. Freeman is an associate professor of economics at Bowdoin College in Brunswick, Maine 04011. Dr. Haveman is professor of economics at the University of Wisconsin, Madison.

ranted degree of acceptance in this debate. Our purposes in this article are to dispell confusion, correct misconceptions, and to put the more substantive of the criticisms of residuals charges into proper perspective. To gain this perspective, we compare the residuals charge strategy with the relevant alternative—in this case direct regulation of discharges through permits backed by an administrative and judicial enforcement system. The regulation-enforcement strategy is the relevant alternative because it is the mainstay of present public policies toward the control of air and water pollution. This explicit comparison between strategies will reveal that the most substantive of the criticisms of residuals charges apply also to the regulation-enforcement strategy. This is because the criticisms stem from the nature of the pollution control problem rather than from characteristics of the residuals charge approach to solving that problem.

We first discuss the rationale for the residuals charge approach to environmental management, describing its economic logic and explaining how it would work in practice. We then address ourselves to the most important misconceptions and critical assertions and conclude with some brief recommendations for public policy which we think are well supported by our discussion.

The Rationale for Residuals Charges

The case for the economic incentives or residuals charge strategy rests on the acceptance of two primary propositions. The first is that, in a market economy, prices play a major and valuable role in the allocation of resources to uses that will be of highest value. The second is that degradable environmental resources, unlike most other resources, are now outside the scope of the market system and the uses to which they are put are not subject to the guidance of prices.

Economic theory teaches us that, given certain assumptions and conditions, markets can solve efficiently or optimally the problem of allocating scarce resources. The ideally functioning market system provides information and signals to economic decision-makers. These signals are the prices of goods and resources. The information they convey concerns the relative gains and costs of using the resources at hand in different ways. Market prices reflect the marginal valuation or willingness to pay for goods on the part of consumers. Costs reflect the value of resources in alternative uses. In the idealized system, the competition for profits leads to an expansion of the production of goods to the point where their prices equal their marginal or incremental costs of production. Thus the amount people are willing to pay for a good equals the value of the resources used in producing it; no more, no less. No more, because producers would otherwise expand output in order to capture the excess of value over cost. No less, because with losses the resource owners would be induced to shift their resources to uses of higher value.

In the case of environmental resources, however, the price signals are absent. Land, labor, and capital have their prices. But environmental resources—public watercourses, the atmosphere, and public lands—have no price because no one owns them. As a result, these resources are treated by everyone as free goods. When scarce resources are made available at a zero price, and with no nonmarket control of their use, they are overused and abused. The "freeness" of the resource results in there being no incentive for the population to economize on the resource or to allocate it to the use of highest value.

Hardin called this the "tragedy of the commons" (*9*). In his apt example of the communal grazing land, each herdsman would introduce more cattle as long as there was any grass left. Since he did not own the pasture land, the herdsman would reckon only the costs to himself of letting in more cattle, and would ignore the costs he imposed on other herdsmen as well as the long-term damages that would be caused by overgrazing. The historical solution to the common grazing problem, at least in Western societies, has been the division of land and the establishment of rights of ownership so that markets and prices would control and ration the use of land.

The atmosphere and our watercourses are the modern equivalents of the commons. Consider air pollution, for example. Because no one owns the atmosphere, people discharging wastes can use it at no cost to themselves. The fact that people living downwind experience bad health and earlier death is a cost of our using the atmosphere in this way. But the market system does not impose these costs on those who are responsible. To the dischargers the use of the atmosphere is free. The availability of environmental resources to users at a zero price results in their overuse and abuse, a phenomenon we call pollution.

When a common property resource, such as the air or water, is being overused, there are two possible solutions. Hardin suggested that the solution was mutual coercion, mutually agreed upon by the majority. The appropriate pattern of usage would be determined by some political process and implemented by some nonmarket means, the police power of the state being relied on to carry out the plan. The licensing of television broadcasting stations and issuing of permits for discharges into navigable waterways are examples of this approach. In essence, this solution is the regulation-enforcement strategy discussed above. The other alternative is to reproduce the effect of private markets by charging a price or fee to those who would use the common property resource. The fee or price would then allocate or ration the resource. Grazing fees per head of cattle on federal lands, stumpage fees for timber cut in national forests, admission fees to national parks, and residuals charges are all examples of the economic incentives approach to managing common property resources.

Under a system of residuals charges, people discharging wastes are required to pay the government a certain sum for each unit of wastes discharged. Dischargers are led to compare the cost of using the environment for waste discharge—as reflected to them by the residuals charge—with the cost of handling their waste disposal problems in some other way. The choice of means for dealing with the waste is left to the discharger. And he has a wide range of options. He may treat the waste, recycle it, store it, or find methods of production which reduce the volume of waste generated (*10*, especially chaps. 4 and 8). His only guide is the relative costs of alternative procedures, one of which is dumping the waste untreated into the environment. People generating wastes will reduce their discharges to the environment as long as the marginal cost of doing so—the marginal cost of waste treatment (or recycling, or waste storage)—is less than the price or marginal cost of discharging the waste to the environment. The higher the residuals charge the greater the incentive to seek alternatives to direct discharge, and the smaller the flow of wastes to the environment. In

this way environmental resources can be brought back into the economic system. The incentives which induce efficiency in the use of labor, capital, and land can also effect a more efficient allocation of environmental resources.

The Regulation-Enforcement Strategy

Policy proposals cannot be evaluated effectively in a vacuum. Any given policy can best be evaluated by comparing it with the relevant alternatives—one of which is to do nothing. In our judgment, the relevant comparison is between a residuals charge strategy and the regulation-enforcement aspects of the present strategy for controlling air and water pollution. This strategy, as embodied in federal and state law, consists of, first, the establishment of ambient air and water quality standards and, second, the use of the police power of the state to bring about a reduction in discharges sufficient to attain these standards.

Given the establishment of quality standards, this approach can best be viewed as a two-step process in which regulations are established and compliance with them is enforced. In establishing regulations, the public authority must determine the maximum allowable total discharges for a river stretch or an air basin, consistent with the attainment of the quality standard. Then the authority must, in some way, allocate this total among all dischargers. This allocation will determine the terms of the licenses or permits that will be held by all dischargers and that will specify the maximum allowable discharges or standards of effluent or emission quality. In enforcing the regulations, the authority must undertake surveillance of dischargers so as to detect violations and must initiate judicial or quasi-judicial proceedings to compel compliance or to impose sanctions (such as fines and jail sentences) when violations are detected.

The ideal situation for performance of a system of regulation and enforcement is one in which there are no violations whatsoever. In practice, the number of violations (whether or not detected) depends on the cost of compliance with the regulations, the penalties associated with being caught in a violation, and the probability of being detected in violation and having the penalties imposed. These are all factors which must be considered in assessing the effectiveness of any regulation-enforcement system.

Residuals Charges, Damages, and Standards

If the residuals charge strategy is to be taken seriously, a satisfactory answer must be provided for the question of what the appropriate charge would be on a particular pollutant. The basic logic of the residuals charge proposal suggests one answer: the charge should equal the marginal or incremental damage caused by the pollutant, as measured in dollars (*10*, see chaps. 5 and 6). This logic is described as follows.

When wastes discharged to the environment impair its use for other purposes, for example, life sustenance or recreation, there is, in principle, a willingness on the part of the affected individuals to pay to avoid these adverse effects. This willingness to pay is the monetary measure of the damages or costs of pollution. Efficiency in the allocation of environmental resources requires that these damages be equated with the costs of their being avoided at the margin. Because people discharging wastes minimize their own costs by equating their marginal costs of waste reductions with the residuals charge, a charge equal to the marginal pollution damages will lead to the efficient allocation of the environmental resource. The reduction in environmental damages associated with a one-unit reduction in discharges will just equal the incremental cost of obtaining that reduction. Where marginal environmental damages exceed marginal waste reduction costs, further reductions in discharges are called for and will be induced in the dischargers as they respond to the charge set equal to marginal damages.

If monetary damages are to be the basis for establishing residuals charges, estimates of these damages must be available. Although economists are making progress in estimating some forms of pollution damages in dollar terms (*4*, p. 104; *11*), sufficiently reliable information for setting residuals charges on this basis is not now available nor is it likely to be in the near future (*12*).

The first misconception regarding residuals charges is the belief that such charges can be implemented only if the magnitudes of the damages are known in terms of dollars (*13*). Fortunately, the economic logic of the residuals charge strategy provides an alternative means of determining the charge that should be imposed—one which is consistent with present legislation and which utilizes available or readily obtainable information.

Under present environmental policies, the federal government has required states to establish standards or minimum acceptable levels for air and water quality. For any such standard there is a maximum permissible rate of discharge of residuals which is consistent with that standard. An appropriate residuals charge, if set high enough, can induce dischargers to limit their discharges to this maximum amount. In economic terms the standard establishes a maximum supply of permissible discharges, and the price (residuals charge) must be set high enough to ration this fixed supply among those who wish to make discharges. In other words, there is a market clearing price or charge which will equate the quantity of discharges demanded with the fixed supply implied by the standard (*14*).

The response of dischargers to the charges imposed depends on the marginal costs that they will incur if they reduce their residuals by treatment and other means. If the public authority responsible for setting residuals charges knows the marginal cost schedules of dischargers, it can readily calculate the appropriate residuals charge. The charge must be set at the marginal cost of waste reduction at the level of control required to attain the standard.

Although information on the costs of reducing wastes is far from perfect, we do have some data. A number of studies have been conducted on the basis of cost estimates obtained for engineering designs of waste reduction methods. While such estimates are not accurate for all dischargers, they do permit analysts to make reasonable projections of the responses of representative dischargers to a charges system, and to estimate the appropriate charges (*4*, p. 120; *15*). Even if the marginal cost of treatment is not known with accuracy, the appropriate charge can be discovered by observing the responses of dischargers when they are presented with alternative charges. If an initial charge fails to attain the quality standard, the charge should be raised until the standard is met (*16*). An added benefit of this approach is that it generates valuable information on the minimum costs of attaining different standards of environmental quality under various environmental conditions and for different types of wastes.

In the remainder of this article we assume that both the residuals charge and regulation-enforcement strategies have as their goal the attainment of quality standards for air and water that have been established by the commu-

nity. These standards can be the basis for determining the charges that should be imposed just as they are the basis for determining permissible discharges under the regulation-enforcement approach. We turn now to an evaluation of some of the criticisms of residuals charges.

Residuals Charges Are Not "Licenses to Pollute"

The most frequently uttered charge against an economic incentives strategy is that it allows those with financial means to buy their way out of effective environmental control. To those offering this criticism, the idea that polluters can purchase the right to degrade the environment through the exercise of economic power has appeared to be both vulgar and a fatal policy flaw.

The "license to pollute" cliché should be laid to rest once and for all. First, it must be recognized that residuals charges are no more a license to pollute than are the allocation of permits issued under a regulation-enforcement strategy. In both approaches it is recognized that some use of watercourses for residuals absorption is appropriate. In both approaches, the quality standard of the stream will be attained if the policy is properly implemented. The residuals charge strategy will achieve the desired reduction in discharges by raising the polluter's cost of discharging; the use of permits will achieve the desired reduction by enforcing the rules implied by license provisions.

With a means of enforcing effluent standards, the license to pollute is, in effect, awarded to the discharger free of charge. The discharge permit is treated as a "right" which is assigned to the polluter by the public. With a residuals charge approach, however, the discharger must pay by the pound for each unit of waste which is released into the environment. He must, in essence, compensate the public for the right to make use of the environment for waste discharge. In this context, the labeling of the residuals charge strategy as a "license to pollute" makes sense only if the effluent standards approach is also so regarded and if the required payment of the charge fails to induce dischargers to search for measures of discharge control or treatment in order to reduce liability to the charge. As we emphasize below, indifference to the residuals charge is not consistent with human behavior as it is revealed in business.

Finally, this assertion fails to recognize that, under a residuals charge strategy, all dischargers face a perpetual incentive to economize on the use of the environment by reducing discharges. Under an effluent standards strategy, only those dischargers who seek to dispose of more wastes than their license entitles them to will face such an abatement incentive.

Would Charges Hinder Industrial Abatement?

Representatives of industry have argued that residuals charges would cripple industry's ability to finance pollution control equipment. Industry, it is claimed, is already spending as much as is possible on efforts to control pollution. "Taking money away from industrial companies in the name of a tax on pollution . . . would harm the cause of pollution control" (*17*).

The vacuousness of this position is evident from several perspectives. First, by implication this assertion contends that economic incentives—prices and costs—fail to influence business decisions and behavior. Observed behavior verified by empirical estimates contradicts this contention. For example, when firms purchase labor-saving capital equipment in response to rising wages, they are demonstrating their responsiveness to economic incentives. It is interesting that, in other contexts, the role of economic incentives in achieving efficiency has been regarded as of primary importance by business decision-makers.

Second, this position suggests that the main effect of any decrease in profits would be to reduce expenditures for residuals abatement or treatment. Without appropriate incentives, it is probable that businesses do afford investments in pollution control low priority. After all, with little effective penalty for discharging wastes, the return on abatement investments will not be high. It is the purpose of a residuals charge policy to alter these priorities and to remove pollution control efforts from their dependence on some notion of social responsibility.

Finally, if continued discharge is made costly through a residuals charge policy, abatement investments will become profitable and, as with profitable labor-saving investments, industry will find the financial resources to undertake these activities.

Although industry expects to spend $4.9 billion on pollution control in 1972, this figure is only 5.3 percent of all planned capital expenditures (*18*). A doubling in the amount of spending for pollution control could be accommodated with only a 5.6 percent reduction in other capital spending. It is not that financial resources are unavailable. Rather, what is lacking is the incentive to use more of these resources for pollution control.

Residuals Charges Similar to User Charges

The practice of imposing sewer (or user) charges on those who discharge wastes to municipal sewer systems is now well established and generally accepted. The municipality accepting the wastes for treatment renders a service and incurs real costs which must be covered by revenues. Some have argued that although user charges are reasonable, residuals charges are not because in the latter case no service that entails cost is rendered (for example, see *17*, p. 1262).

The argument is invalid. Although there are some differences, the cases of user charges and residuals charges are alike in two essential respects. First, in both cases a service of value is rendered to those who discharge wastes. In one case this service is provided by a system constructed and operated by human beings and employing labor and capital; in the other case the service is provided by a natural system (*19*). Second, the use of both systems for waste disposal entails real social costs. In one case, these are the opportunity costs of the labor and capital utilized in treating the wastes; in the other case the costs are imputed damages in the form of recreation opportunities foregone, medical costs incurred, and longevity sacrificed. It is the existence of these costs and the absence of any institutions for imposing these costs on those who use the environment for waste disposal which make pollution a problem for public policy.

On a somewhat different level, the issue here is a legal one involving property rights. User charges, it is implied, are legitimate because the legal rights to the treatment facility are well defined. But because the ownership rights in the environment are not well defined, it is argued that residuals charges are not legitimate. Dischargers are, in effect, asserting that they have a right to the assimilative capacity of the environment and, therefore, should not have to pay anyone else for its use.

While the question of ownership of environmental resources has not been finally resolved in the law, the thrust of recent legislation and case law is in opposition to the position outlined above. These legal developments have tended to assert public ownership in the common property resource (*4*, pp. 104 and 155–177; *20*). The recent passage of laws containing licensing requirements supports this view. And a residuals charge policy would simply assert that what the public has the right to give away through licenses it can also charge a price for.

Discharges Can Be Measured

In order to impose residuals charges it must be possible to measure residuals flows directly or to estimate their magnitudes by accurate indirect means. For a residuals charge system to provide appropriate incentives to dischargers, the bill paid by the discharger must vary directly and closely with the composition and quantities of wastes actually discharged. Several observers have argued that because accurate monitoring of residuals flows is not practical, a residuals charge is not a feasible alternative (*21, 22*). However, the argument will not stand closer inspection.

Any pollution control strategy requires that information be obtained on what is being discharged in order for the strategy to be effective in controlling or restricting discharges to some maximum amount. For example, if an effluent licensing system is to be strictly enforced, the policing agency must be able to measure discharges accurately, continuously, and at reasonable cost in order to detect and take action on violations of the license terms. Fortunately, for most of the more significant and ubiquitous pollutants the measurement technology is available and its cost is reasonable relative to the other costs and benefits associated with pollution control (*23*).

Must Pollution Control Costs Be Known?

While both a residuals charge strategy and a regulation-enforcement approach have identical requirements for information on rates of discharge, they differ in their requirements for information regarding the costs of reducing waste discharges. Under a regulation-enforcement system, the objective is to issue licenses which restrict discharges sufficiently to attain the environmental quality standard. The total allowable discharge could be allocated among licensees in an infinite number of ways. No information is required on the costs borne by the dischargers in order for them to meet the standard. For the residuals charge system to achieve precisely the desired environmental quality, a charge structure must be established that will induce individual dischargers to reduce their effluents. To ascertain the appropriate charge, policymakers should be able to estimate the costs of such reduction incurred by individual dischargers.

However, the capacity to achieve precisely a desired environmental quality is only one of several criteria that might be used to evaluate policy. A further relevant factor is the total cost to society of achieving the standard. Although any set of permitted discharges can achieve the standard, only that set of license allocations which equates the marginal costs of waste reduction of all dischargers will achieve the standard at minimum total cost. Departures from this rule are likely to raise total costs substantially. For example, studies have shown that the imposition of requirements for uniform treatment may entail total costs which exceed the minimum costs by a factor of 2 (*4*, p. 120; *15*).

A residuals charge strategy has the virtue of leading automatically to the achievement of any given reduction in discharges at the lowest possible cost. This is because each polluter will reduce his discharge to the point at which the cost of reducing it by one more unit is just equal to the residuals charge imposed—the equal marginal cost condition for cost minimization. For that charge to be selected which will exactly attain the target, however, information must be available on the costs of reducing discharges at all sources.

In sum, in the absence of perfect knowledge concerning the costs of waste reduction, a regulation-enforcement system can achieve the quality standard but at a total cost which is likely to be substantially above the minimum attainable. Under similar circumstances, the residuals charge system will achieve pollution reduction at minimum cost, but will necessitate some iterative (trial and error) experimentation with charges in order to find the exact charge at which the quality standard is attained (*16*). Because of inefficiencies due to temporarily unstable charge structures, total costs may be somewhat above the minimum. However, increases in total costs due to temporary instability in charges are not likely to be as large as the cost of the inefficiencies that are built into the regulation-enforcement system.

Residuals Charges, Regulation, and Inflation

Will residuals charges, through their impact on production costs, raise prices and lead to inflation? First, we must distinguish between inflation (continuously rising prices for all goods) and a once-and-for-all increase in the relative prices of goods responsible for large amounts of pollution. Any effective pollution control strategy will have the latter effect unless accompanied by a full public subsidy of pollution control costs. But, there is no obvious reason why such an increase in the relative prices of some goods should generate or sustain a continued increase in the prices of all goods (*24*). We will confine our attention to the differential impact of the two strategies on relative and first-round aggregate price movements.

The basic point to be emphasized is that price increases for goods giving rise to large amounts of residuals are themselves an instrument of pollution control. Higher prices cause reductions in the quantities demanded and corresponding reductions in pollution. A residuals charge policy will automatically have this effect. To the extent that a regulation-enforcement policy is successful in inducing pollution control activities, it, too, will induce higher costs and prices in commodities that give rise to residuals as by-products, and, hence, discourage their consumption. Both strategies will tend to induce price increases for products contributing to pollution.

Let us, on the one hand, assume that a residuals charge has been imposed which is just sufficient to achieve the environmental quality standard. Dischargers respond by some combination of reducing residuals discharges and paying the charge on the remainder. Both kinds of responses increase the total costs to the dischargers.

Alternatively, let us assume that under a regulation-enforcement strategy licenses have been issued which curb discharges sufficiently to achieve the environmental quality standard. In the absence of complete information on costs of residuals reduction, the allocation of licenses and pattern of discharges are

likely to be different from the least cost pattern of discharges achieved by the residuals charge strategy. For all dischargers together, the total costs of treatment will be greater than under the residuals charge approach, and the distribution of these costs among dischargers will be different. Firms with the highest marginal costs of treatment will experience greater increases in costs under regulation than with the residuals charge, since they will not have the option of paying the charge if that is cheaper. And if all cost increases are passed forward as price increases, regulation will have a relatively greater effect on the prices of those goods that cost the most in terms of residuals treatment.

The two strategies will also have a differential impact on the aggregate price level. At first blush, one would expect that a residuals charge strategy designed to attain a given standard of air or water quality would entail a greater increase in the prices of pollution-causing goods than would a regulation-enforcement strategy. After all, with a residuals charge, people discharging wastes are being forced to pay a "rent" on their use of environmental services in addition to incurring costs for residuals reduction. A closer look, however, suggests that this conclusion is not necessarily correct. As we pointed out earlier, a regulation-enforcement policy implemented with incomplete information regarding the costs of reducing discharges may entail increases in total costs of up to twice the minimum increase in cost necessary to achieve the quality standard. Thus, the regulation-enforcement approach, because of its inefficiency, may well have a larger effect on prices overall than the residuals charge approach that requires collection of environmental rent (*25*).

Whatever effects the various strategies have on differential prices, price increases in general are not likely to be substantial. The effect of any pollution control policy on product price depends in part on the production technology, specifically the ease with which the services of capital and labor can be substituted for the heretofore free waste assimilation services of the environment. The results of numerous studies indicate that there are many substitution possibilities, and that the elasticity of substitution in production is fairly high (*10*). This in turn means that the impact of pollution control policies on production costs and prices will not be as severe as is often implied.

The second report of the President's Council on Environmental Quality makes the same point. It is shown that even if all industries undertake secondary waste treatment by 1974 the annual costs of water pollution control will be less than 1 percent of the value of shipments for almost all industries. In general, such costs would have a smaller impact than a 5 percent increase in wage costs. Annual costs of reducing air pollution so that the standards of the 1970 Clean Air Act are met are estimated to be less than 1 percent of the value of shipments for nearly all industries (*4*, p. 123).

Market Power and Residuals Charges

It has been argued that those firms with market power can escape the incentive effect of residuals charges by the expedient of raising prices sufficiently to pass the full amount of the charge on to the consumer. Again, there are several points to be made. First, as we pointed out above, even if a proportional price increase were the only consequence of a residuals charge, pollution would be curbed somewhat through the consumption effect of the price increase. But to argue that this would be the only effect does not square with evidence on the operation of the economic system.

Second, even the firm with sufficient market power to raise its price is not likely to do only that. If it is a profit maximizer, it will reduce discharges as long as the marginal cost of doing so is less than the charge. In this way it responds to the charge in the same manner as a firm in a competitive industry.

The modern view of the corporation de-emphasizes profit maximization as the primary determinant of the behavior of a firm, partly because profit-maximizing behavior cannot be defined in the case of oligopolistic industries, and partly in recognition of the complexity of the corporation as an organization. But the reduced emphasis on profit maximization as a goal does not lead to the conclusion that the residuals charges will have no effect on firms' decisions with respect to discharges. It can easily be shown that as long as firms attempt to minimize the costs of producing whatever level of output they have chosen, a residuals charge will induce the appropriate reduction in discharges (*26*).

This conclusion is less strong, however, in those cases where even cost-minimizing behavior cannot be expected. Governmental units (for example, municipalities) and rate-regulated public utilities are two examples. However, external budgetary pressures are likely to assure the appropriate response from municipalities, especially for such highly visible costs as a residuals charge on municipal sewage disposal or trash incineration.

The response of regulated utilities possessing guaranteed rates of return on capital is less clear. In a permissive regulatory environment, utility commissions might permit firms to pass on the entire residuals charge through higher rate structures. In this case, the charge would have no effect on the amount of discharges except through the reduction in consumption. However, even in such a permissive environment, the lag between imposition of the charge and the adjustment of rates would entail some loss of profits—and, hence, provide some incentive for abatement activities. Regulated firms also have an incentive to choose control techniques that are capital intensive and that can be included in the rate base rather than other, perhaps lower-cost alternatives such as fuel substitution. Thus the effect of a residuals charge on a regulated utility is more problematical than an equivalent charge imposed on an independent business firm.

The Administration has proposed a tax on the emissions of sulfur oxides. This tax will fall primarily on regulated electrical utilities that use fossil fuels. If enacted, the stimulus for abatement activities provided by the charge may well be weakened and distorted. Nevertheless we believe that a well-designed tax on sulfur oxides which is keyed to air quality standards is likely to be more effective than direct regulation and enforcement of emissions standards.

Charges and Environmental Management

In a recent paper Roberts concluded that for the case of water quality, residuals charges would make implementation of a comprehensive environmental management program more difficult (*21*, p. 1554). He suggested that it would be more difficult to make full use of collective facilities, such as large-scale treatment plants or low-flow augmentation, if residuals charges formed the basic strategy. This argument appears to us to be without substance (*27*). Indeed, comprehensive plans of river

basins must be the basis on which the appropriate effluent charge schedules are calculated. And if these plans reveal collective facilities to be part of the least-cost plan, such facilities should be built. Moreover, the logic on which the argument for effluent charges is based also tells us how the collective facilities should be financed. User charges should be based on the marginal cost of waste treatment at the collective facility. Appropriate user charges and effluent charges must be integrated and mutually consistent because they both depend on the water quality standards to be met, the costs of collective treatment, and the costs of private waste reduction.

Administration of Residuals Charges

Defendants of the present regulatory-enforcement strategy have repeatedly stated that residuals charges would be administratively too complex to be workable (*28*). This position stems from a fundamental misconception of the regulatory-enforcement process. It is in the American tradition to create regulatory agencies to deal with problems caused by malfunctionings in the economic system. The existence of agencies such as the Interstate Commerce Commission, Federal Power Commission, and Food and Drug Administration is sufficient to convince most people that the problems for which these agencies were created are being dealt with successfully. But a careful analysis of the evidence shows that this is rarely the case (*29*).

The naive view of the regulatory process is that an agency establishes rules and regulations to govern the behavior of the regulated and to further the public interest. The threat of sanctions is deemed to be sufficient to deter violations; but if any occur, violators are quickly brought to justice. The reality is quite different. The enforcement of regulations is essentially a political process entailing bargaining between parties of unequal power (*30*). In this process the real issues are camouflaged in technical jargon, and the regulators are largely protected from political accountability for their actions. The regulatory agency and the interests they regulate bargain over the regulations to be set. They bargain over whether violations have occurred and if so who was responsible. They bargain over what will be acceptable actions to correct infractions. And in the rare instances where the bargaining process breaks down and the conflict moves to the courts for resolution, the judicial system seeks reasonable accommodation and acceptable compromise. Only rarely is it forced by the flow of events into making either/or choices. At every stage of this multilevel bargaining process those being regulated have a lot at stake, while the public interest is diffuse, poorly organized, and poorly represented. Predictably the bargains struck favor those being regulated. The upshot is that the more numerous the decisions and the further removed they are from elective politics, the less likely it is that these decisions will serve the public interest.

The regulatory-enforcement approach to pollution control suffers from all these faults. In the case of the efforts made by the federal government to control air pollution, this is amply documented (*2*). The history of federal enforcement of regulations aimed at the control of water pollution is no better. On the basis of past experience with the regulatory process, it would seem that the burden of proof of its effectiveness should lie upon those who advocate its continued application to the problem of pollution control. However, we believe that the residuals charge strategy will be administratively simpler and more effective than regulation; and we think the point can be made relatively easily.

In order to evaluate this claim, we must first specify the characteristics of the residuals charge system which we have in mind. Given that environmental quality standards have been set, a single per-unit charge would be levied on each of the prominent harmful substances found in effluents or emissions. Each discharger would be responsible for monitoring his discharge, reporting its composition and quantity to the public authority, and making the appropriate payments. There is an obvious comparison with the system of reporting and paying corporate income taxes. As in the case of the income tax, rules and standards of accuracy for measurement would have to be specified and audits for compliance would have to be undertaken. Dischargers would be required to install and maintain the required monitoring equipment, subject to audit and calibration for accuracy by the authorities. Information on discharges and payments would be recorded and made available for public scrutiny.

With such a system there is little room for administrative discretion and bargaining. The primary decision is the actual charge to be imposed, and this decision is a significant and highly visible one. There is also a clear performance criterion by which one can judge whether the rate of charge is satisfactory. If environmental quality standards are being met, the rate is high enough; if not, the rate should be raised. Finally, while the history of regulation suggests that the zeal and effectiveness of the regulatory agency diminish over time, the effect of a residuals charge is durable. It remains effective unless the real cost of a fixed charge is eroded by inflation or unless there is an explicit political decision to remove it.

The conclusion with respect to administrative feasibility is a strong one: a residuals charge system poses no unique or particularly difficult administrative problems. Rather it is an administratively simple strategy which avoids many of the pitfalls of the regulation-enforcement approach and which leaves less room for powerful interests to gain special advantages through low visibility negotiations with the regulatory agency.

It has also been suggested that effluent charges are administratively cumbersome because the optimal charge structure must vary over the seasons and with variations in the stream flow or meteorological changes (*21*, p. 1554). It is seldom recognized, however, that these same factors dictate the variability over time in the terms of the discharge permits issued under the regulation-enforcement strategy. Residuals discharge permits should allow higher discharges during periods of high assimilative capacity while calling for reduced discharges (or perhaps no discharges at all) during critical periods of low stream flow or atmospheric temperature inversion. A license system with a constant maximum allowable rate of discharge is no better or worse in this respect than a residuals charge system where the price is constant all the year round. Seasonal and other variations can and should be included in either strategy.

Conclusion

It is our judgment that the arguments examined here do not form a strong case for rejecting the residuals charge strategy. Indeed, quite the opposite. When we consider the failure of the cur-

rent regulation-enforcement approach and, in particular, its political and administrative difficulties, a new environmental strategy which minimizes its reliance on regulation-enforcement and which emphasizes the use of economic incentives to achieve changes in behavior seems desirable on practical as well as theoretical grounds. We believe that the time has long since come to move ahead with some limited and carefully prepared experiments with residuals charges. We will never know whether they are a viable new approach unless we try them out.

One form of potentially fruitful experimentation would be a federally established charge or tax on emissions of sulfur oxides. The Administration's long delayed bill to tax the sulfur content of fuel could provide the basis for such an experiment. The proposed tax on lead additives in gasoline could well serve the same function (*31*). However, for the automotive emissions problem, we would urge instead the systematic use of residuals charges in the form of a "smog tax" or charge on actual auto emissions (*32*).

Turning to the case of water pollution, we have already suggested an experiment based on the establishment of a single river basin authority with responsibilities for air and solid wastes as well as water pollution. The authority would establish a system of residuals charges as well as foster the construction of whatever collective treatment facilities are appropriate (*33*). In lieu of experimenting with an entire river basin, the federal government could establish a nationwide uniform effluent charge on a single substance (*34*).

To sum it all up, the conclusion of the 1971 annual report of the Council on Environmental Quality can only be applauded (*4*, p. 136):

> It is . . . clear . . . that because of the enforcement, efficiency, and equity problems of the regulatory approach, other means of achieving pollution abatement must also be probed.

References and Notes

1. R. H. Haveman, in U.S. Congress, Joint Economic Committee, *Economic Analysis and the Efficiency of Government*, pt. 6, *Economic Incentives to Pollution Control*, Hearings before the Subcommittee on Priorities and Economy in Government, 12 and 19 July 1971 (Government Printing Office, Washington, D.C., 1971), p. 1186; J. M. Fallows, *The Water Lords* (Grossman, New York, 1971).
2. J. C. Esposito, *Vanishing Air* (Grossman, New York, 1970).
3. A. V. Kneese, *Public Policy* **19**, 37 (1971); Office of the Comptroller General, *Examination into the Effectiveness of the Construction Grant Program for Abating, Controlling and Preventing Water Pollution* (Government Printing Office, Washington, D.C., 1969).
4. President's Council on Environmental Quality, *Environmental Quality, 1971* (Government Printing Office, Washington, D.C., 1971).
5. Testimony of the Sierra Club, Friends of the Earth, Environmental Action, National Audubon Society, and National Wildlife Federation, in U.S. Congress, Joint Economic Committee, *Economic Analysis and the Efficiency of Government*, pt. 6, *Economic Incentives to Pollution Control*, Hearings before the Subcommittee on Priorities and Economy in Government, 12 and 19 July 1971 (Government Printing Office, Washington, D.C., 1971), pp. 1191–1241.
6. President Nixon's Message to Congress on the Environment, 8 February 1972. See also House bill HR 10480, introduced by Congressman Les Aspin, 92nd Congr., 1st Sess.
7. Senate bill S-3181, 91st Congr., 1st Sess.; reintroduced as S-2696 on 15 October 1971. See also U.S. Congress, *Congr. Rec.*, 2 November 1971, S 17425.
8. *Vermont Statutes Annotated*, Title 10, chap. 33, subchap. 1, especially section 912a. The charges were to become effective on 1 July 1971, but implementation has now been delayed 1 year.
9. G. Hardin, *Science* **162**, 1243 (1968).
10. See A. V. Kneese and B. T. Bower, *Managing Water Quality: Economics, Technology, Institutions* (Johns Hopkins Press, Baltimore, 1968).
11. A. V. Kneese, in *Social Sciences and the Environment*, M. E. Garnsey and J. R. Hibbs, Eds. (Univ. of Colorado Press, Boulder, 1968); L. B. Lave, in *Analysis: Theory and Method in the Social Sciences*, A. V. Kneese and B. T. Bower, Eds. (Johns Hopkins Press, Baltimore, 1972); L. B. Lave and E. P. Seskin, *Science* **169**, 723 (1970).
12. The Vermont law stipulates that charges shall "approximate in economic terms the damage done to other users of the waters" [see (*8*)]. The lack of data on pollution damages has forced the state to postpone implementation of its charge system.
13. See, for example, the debate on Senator Proxmire's proposal to amend the Muskie "Clean Water" bill of 1971, U.S. Congress, *Congr. Rec.*, 2 November 1971, S 17429.
14. See J. H. Dales, *Pollution, Property, and Prices* (Univ. of Toronto Press, Toronto, 1968), for a proposal to sell a limited number of pollution permits.
15. E. Johnson, *Water Resour. Res.* **3**, 291 (1967); Federal Water Quality Administration, *Mathematical Programming for Regional Water Quality Management* (Government Printing Office, Washington, D.C., 1970); R. K. Davis, *The Range of Choice in Water Management: A Study of Dissolved Oxygen in the Potomac Estuary* (Johns Hopkins Press, Baltimore, 1968).
16. See J. E. Hass, *Water Resour. Res.* **6**, 353 (1970).
17. This statement and the elaboration of this position can be found in congressional testimony of H. C. Lumb, vice president of Republic Steel Corp., in U.S. Congress, Joint Economic Committee, *Economic Analysis and the Efficiency in Government*, pt. 6, *Economic Incentives to Pollution Control*, Hearings before the Subcommittee on Priorities and Economy in Government, 12 and 19 July 1971 (Government Printing Office, Washington, D.C., 1971), p. 1254.
18. *Business Week*, 13 May 1972, p. 77.
19. It should be noted that man is able to augment the capacity of natural systems to provide these services through such things as low-flow augmentation and in-stream reaeration.
20. J. Sax, *Defending the Environment* (Knopf, New York, 1970).
21. M. J. Roberts, *Harvard Law Rev.* **83** (No. 5), 1551 (1970).
22. ———, *Public Policy* **19**, 75 (1971).
23. While it is true that there is no machine capable of continuously measuring and recording the biochemical oxygen demand of water discharges, there are other measures of the organic content of waste waters, for example, total noncarbonate carbons; and equipment is marketed for continuous recording of these variables. In other instances, comparisons of the known inputs of a chemical into a process with measurements of the materials recovered can be used to estimate the quantities lost to the environment. It should also be emphasized that it is more important that such monitoring systems be able to detect changes in the rate of discharge than that they measure the absolute level of discharges with precision. For example, a standard chassis dynamometer test for an automobile will provide only a very crude estimate of what the total emissions will be for 1000 miles of driving under road conditions. But the test is capable of detecting relatively small differences in the pollution capacity of two different cars or the same car at two different points in time.
24. It should not be concluded that such an effect is impossible. However, estimation of its likelihood requires the analysis of dynamic macroeconomic theory and the evaluation of the role of expectations and money illusion.
25. We would also emphasize that the residuals charge collected after all adjustments have been made and after the quality standard has been met is, in effect, an income transfer from residuals dischargers or the consumers of their products to the public. It is compensation for the residual environmental damages implied by the quality standard. These real residual damages would exist if the quality standard were met by means of the regulation-enforcement approach. However, they would not then be compensated.
26. W. J. Baumol and W. E. Oates, *Swedish J. Economics*, **73**, 42 (1971).
27. A. M. Freeman III and R. H. Haveman, *Public Policy* **19**, 53 (1971).
28. U.S. Congress, *Congr. Rec.*, 2 November 1971, S 17427.
29. P. MacAvoy, Ed., *The Crisis of the Regulatory Commissions* (Norton, New York, 1970).
30. M. Holden, Jr., *Pollution Control as a Bargaining Process* (Publ. No. 9, Cornell University Water Resources Center, Ithaca, N.Y., 1966).
31. See the testimony of A. M. Freeman III on this bill in U.S. House of Representatives, Committee on Ways and Means, in *Hearings—Tax Recommendations of the President* (91st Congr., 2nd Sess., September 1970), p. 365.
32. See D. M. Fort, W. A. Niskamen, A. H. Pascal, W. Sharpe, "The Smog Tax," reproduced in *Hearings—Tax Recommendations of the President* (91st Congr., 2nd Sess., September 1970), p. 369. The administrative machinery to try the smog tax on an experimental basis is already in place in New Jersey, where automobiles will soon be checked for compliance with state emissions standards as part of their annual state inspection. The results of the emission checks could be the basis for determining a tax factor assigned to the automobile owner to be applied to gasoline purchases. A high rate of emissions would result in a high tax factor, providing the owner with an incentive to have his car better maintained, to install control devices that would improve its emission rating, and to drive less, or it might induce the owner to buy a car with a lower rating.
33. A. M. Freeman III and R. H. Haveman, *Public Policy* **19**, 71 (1971). Because the imposition of residual charges by individual states might distort decisions concerning the location of industries and create a climate of interstate competition to retain or attract wet process industry, a federal residual charges approach is to be preferred.
34. We are not the first to have proposed this [see (*3*)].